Upper Ocean Dynamics and Horizontal Variability in Low Winds

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LONG-TERM GOALS

Our long-term goal is to observe and understand the temporal and spatial variability of the upper ocean and to identify the processes that determine that variability. Air-sea interaction is of particular interest, but we will also investigate the coupling of the sub-thermocline ocean to the mixed layer. We seek to make observations over a wide range of environmental conditions with the intent of improving our understanding of upper ocean dynamics and of the physical processes that determine both the vertical and horizontal structure of the upper ocean.

OBJECTIVES

Little work has been done to explore air-sea interaction and upper ocean dynamics in very light winds, and few observations are available that describe the mesoscale and smaller scale horizontal variability of the upper ocean in such conditions. The objectives of this work are to observe and understand in low wind conditions: (1) how and why the vertical structure and properties of the surface boundary layer of the ocean (roughly the upper 20 to 50 m) evolve in time, and (2) how and why this evolution varies at horizontal lags of 10s of meters to 10s of kilometers on time scales of minutes to months. To do so we seek to observe and identify: (1) the processes that spatially modulate the vertical structure of the upper ocean (including the depth, salinity, temperature, and velocity of the mixed layer), (2) the processes at work at the base of the mixed layer (such as entrainment), and (3) the air-sea exchanges (fluxes of heat, freshwater, and momentum) that couple the boundary layers on horizontal scales of tens of meters up to 100 km.

APPROACH

We are working within a collaborative low-wind research effort, which is part of the Coupled Boundary Layers, Air-Sea Transfer program known as CBLAST-LOW and includes observational and modeling elements. The fieldwork will be done south shore of Martha's Vineyard. At that location, approximately 4 km south of the island in 19 m of water, an air-sea interaction tower will be installed to make detailed measurements of the fluxes, mean vertical profiles, and boundary layer vertical structure. The tower site is close to the Martha's Vineyard Coastal Observatory (MVCO), which will provide power, data communications, and supporting shore measurements; and winds there are predominantly light and from offshore (from the south to southwest) during the summer. A light research aircraft (LongEZ) will fly over the tower and out over the ocean, investigating the structure of the atmosphere out to 40 km upwind of the tower and using infrared to map sea surface temperatures

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14. ABSTRACT
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(SSTs). Satellite data on SST and surface roughness will be collected as well. Collaboration with modelers will use the observations and parameterizations based on them to examine and improve the performance of atmospheric and oceanic models; the models will also be used to guide the interpretation of the data.

In our component of CBLAST-LOW we will observe the vertical structure of temperature, T(z), of salinity, S(Z), of horizontal velocity, U(z), with vertical resolutions down to 0.1 m at a number of points separated by several m to 10's of km and will observe the surface forcing and how it varies horizontally. Temporal resolution will be at least 1 minute. To accomplish this several measurement platforms will be used. The first will be minimally intrusive, Lagrangian buoys supporting vertical arrays to examine near-surface vertical structure. The second will be horizontal arrays, using oil-booms to sample densely at small horizontal lags, supporting vertical sensor strings roughly every 10 m along a 100m surface array, and sword-fishing longline technology to extend sampling to many kilometers. The third will be a two-dimensional mesh to float on the surface and support vertical strings of instruments, thus allowing us to sample in 3-D. The fourth will be small surface buoys capable of supporting a meteorological package and current meters as well as temperature and temperature/conductivity recorders. These small buoys can be deployed independently as surface moorings or attached to one end of the 2-D arrays.

Our experimental plan is to deploy the 3-D array close to the site of the tower, one surface mooring 40 km upwind from the tower, and another surface mooring 20 km upwind from the tower and then to use the 2-D arrays and drifting buoys to sample at various lags from the tower of between several hundred meters and 40 km. In this way we can observe the surface forcing and temporal evolution of the vertical structure of the upper ocean at several locations and contrast these observations with each other and with those at the tower; and, in addition, we can sample the horizontal variability on meter to 10s of km scales.

The timeline for the effort is as follows: in calendar 2000, acquire equipment; in calendar 2001, design and test the platforms and carry out a pilot experiment south of Martha's Vineyard to test the arrays and refine the sampling strategies; in the summer of 2002, carry out the main, collaborative experiment in July and August south of Martha's Vineyard; and after that to follow the field work with collaborative analyses and publication and presentation of results.

WORK COMPLETED

In late 2000 work was begun on acquiring instrumentation and designing the platforms. The greatest challenge was the 3-D array, so one focus of the work to date has been on designing, building, testing, and using the 3-D array in the pilot experiment in the summer of 2001. The 3-D array (Fig. 1) is made up of a net, 200 m by 200 m on a side with 20 m grid spacing. This net is made from foam-core fishing line and is deployed at the sea surface, held there under tension by anchors and surface flotation at each corner. The 3-D array was deployed in June 2001 without instrumentation from a fishing trawler, *FV Nobska*, to work out the logistics of deploying, unfolding, anchoring, and then recovering the array. At the same time, we deployed an array of 6 bottom-mounted temperature, salinity, pressure instruments spanning the southern shore of Martha's Vineyard and the planned domain of CBLAST-LOW. The later set of instruments was deployed to improve our knowledge of tidal flows on the south side of Martha's Vineyard both by observation and by supplying the ocean modelers in CBLAST-LOW with data they could work to replicate.

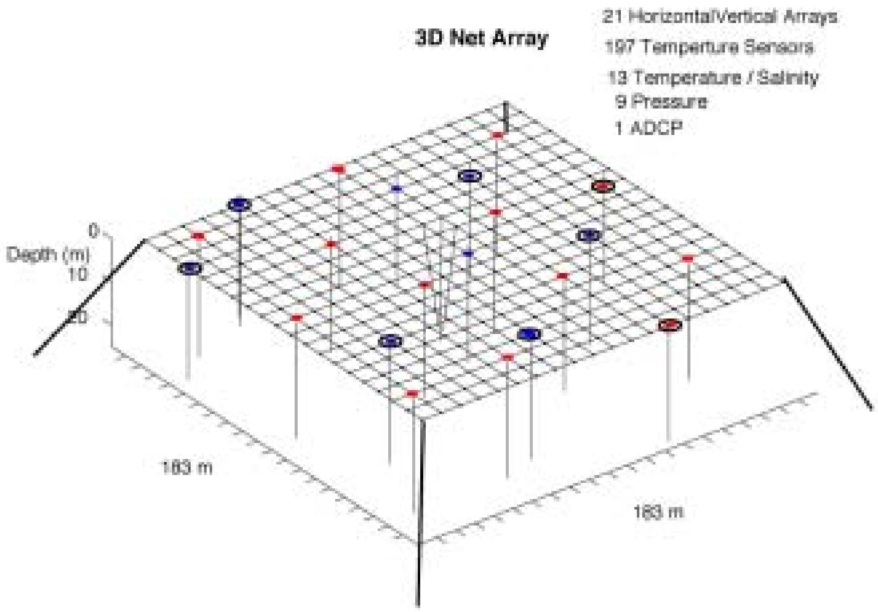

Figure 1. Drawing of the 3-D array, roughly 200 m on a side, with a 20 m grid on the surface and 21 vertical strings of instruments hanging down 25 m. Each of the corners is supported at the surface by a large float attached to anchors used both to moor and tension the surface grid.

In July 2001 we carried out a pilot experiment. Surface moorings were deployed at the 40 km and 20 km upwind sites and left in until mid-August, collecting a month of data; these obtained records of the surface forcing and temporal evolution of the vertical structure. For a week in July, we set and instrumented the 3-D array at the site to be used for the main experiment. Twenty vertical strings of instruments were attached to the 3-D array with instruments from the surface down to 25 m, and a Doppler profiler was hung from the center of the net. We also deployed a trial longline array 1 km in length perpendicular to the shoreline. After 3 days we recovered the longline array. After 5 days we recovered the 3-D array. While on site during that week, 135 CTD profiles were collected, including two sections from the tower site to 40 km offshore and one section parallel to the shore. The 6 bottom-mounted temperature, pressure, salinity instruments with recovered in mid-August with the surface moorings.

RESULTS

Results from the 2001 pilot study fall into two categories. First, lessons were learned on the feasibility and logistics of the experimental approach. Second, we have early findings from the analysis of the data collected during June –August 2001.

We established that it is possible to design, build and deploy a 3-D sampling array and for it to survive in the presence of tidal currents and a wide range of wind and wave conditions. The carefully designed anchor/tensioning system worked well and the array did not move through the duration of deployment. The 3-D array that was aligned parallel to the 27 –30 m isobath did bow slightly under peak tidal conditions. However, the grid cells only distorted by approximately 10 m or half the length of one cell. Early results from the 3-D temperature, conductivity and velocity data collected from the array appear

very encouraging. Figure 2 shows two series time snap shots from temperature data collected at the surface and 4 m level processed using objective analysis methods. Spatial structure and clear changes in the upper mixed layers temperature structure are indicated over the 15-minute interval shown. This analysis will eventually be extended into 3-D and give a good description of temporal/spatial development of the mixed layer over a range of horizontal distances spanning from 60 –200 m and down to a depth of approximately 20 m.

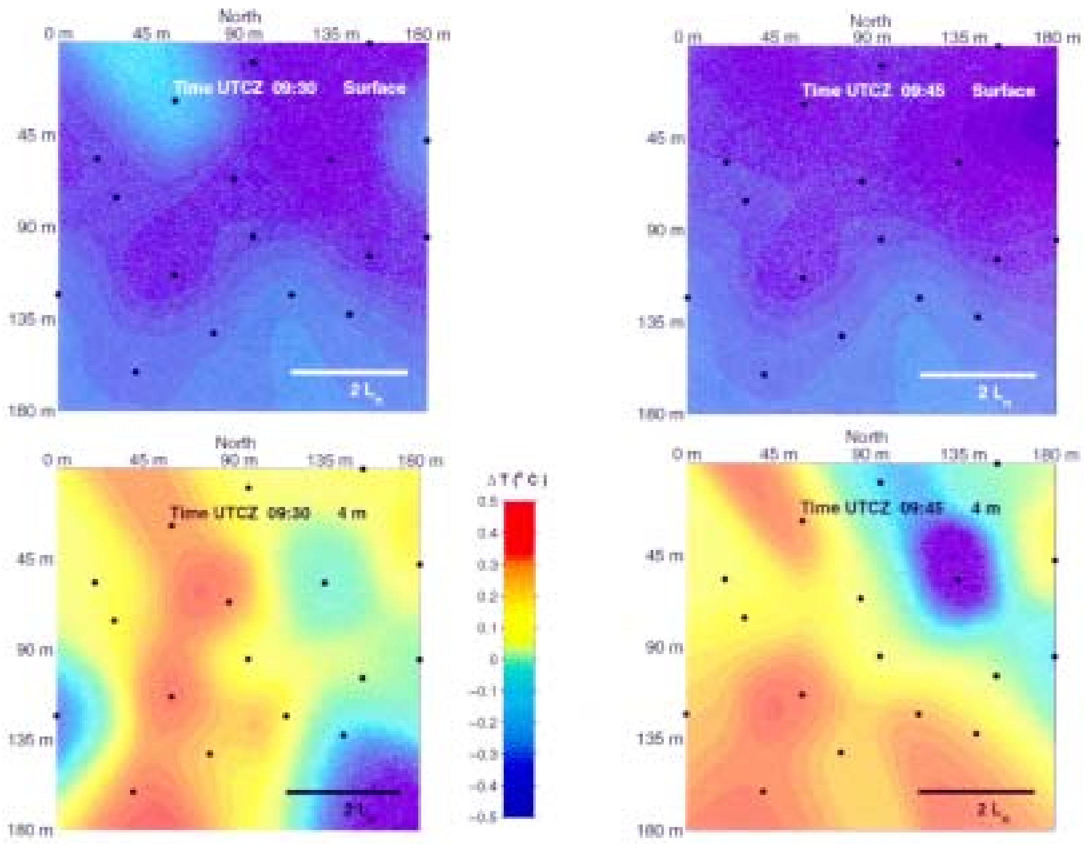

Figure 2. Two sets of temperature maps. On the top row are surface temperatures 15 minutes apart; on the bottom are 4 m temperatures 15 minutes apart and at the same times as those above. The mean temperature at each depth has been removed; and the anomaly from that is shown, with the magnitudes indicated by the color bar.

Longer scales of spatial variability were investigated using different methods with mixed success. Four CTD transects, one running a long-shelf at the 25 m isobath and the other three made across-shelf from 9 m water depth (where the tower will be) out to a depth of 40 m some 35 km off shore show the larger context, including the spatial scale structure of the mixed layer south of Martha's Vineyard and its change over the pilot experiment.

One of the original methods proposed to examine large-scale spatial variability, the instrumentation of longline arrays, was found not to be practical due to extensive fishing activity in the study area. Trials with a 1 km section also indicated that as the line is distorted and/or advected it easily becomes

tangled. Measurement of the larger scale variability looks far more feasible using individually (GPS) tracked drifting buoys that were also tested during the pilot experiment.

The deployment and recovery of the surface buoys and the bottom mounted pressure transducers (tide gauges) were another success. Meteorological data from the surface buoys will be compared with those collected from the Long-EZ aircraft and satellite images. Current meter data from the moorings and arrays will also be used to provide tidal data for the modeling efforts. The intensively instrumented temperature and salinity measurements recorded at the offshore surface buoy site will be used to make comparisons will a 1-D model (PWP) of the mixed layer.

IMPACT/APPLICATIONS

We believe that this work will provide some of the first direct observations within a volume in the upper ocean and thus some of the first assessments of horizontal variability of upper ocean structure on scales of up to several 10s of km and its relation surface forcing and oceanic processes. It will establish the representativeness of the studies to be done at the tower in CBLAST-LOW and be the bases for better understanding the sources of horizontal variability in the upper ocean in low winds.

TRANSITIONS

The 3-D array technology and the knowledge of horizontal variability gained with will both be made available. Data from such arrays can be used to motivate improvements to models (such as LES models) and to provide realistic structures for examining sound propagation in the upper ocean.

RELATED PROJECTS

This work is closely related to our studies of horizontal variability and predictability underway now with support from one of the Secretary of the Navy/Chief of Naval Operations Chairs. That work has focused on the impact of environmental variability on mine countermeasures activities in the shallow water. We have deployed instrumentation to collect data in exercises both in the Gulf of Mexico and off Camp Pendleton. CBLAST-LOW has benefited directly from the development of light surface moorings, instrumentation, and data telemetry methods used in those exercises. In return, CBLAST-LOW, with its explicit sampling of the horizontal as well as vertical and temporal dimensions, will be of great help in assessing how well a single surface mooring can provide adequate information about oceanographic and meteorological variability in a specific region.

REFERENCES

PUBLICATIONS

A combined cruise and data report is in preparation.

PATENTS